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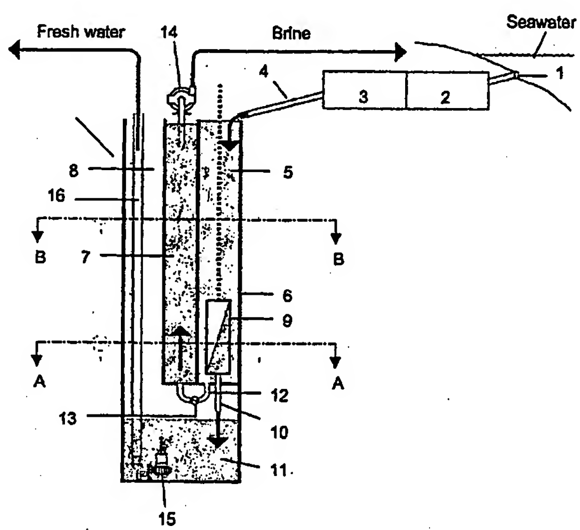
(54) Title: DESALINATION APPARATUS AND METHOD



(57) Abstract: The invention discloses a desalination plant that permits the gravitational flow of seawater (1) to be pre-treated (2,3) and subsequently to flow into a unit cell (5) submerged below soil surface. Reverse osmosis desalination units (9) are maintained in each unit cell (5). Reverse osmosis takes place due to hydrostatic pressure difference in the unit cell (5) and the storage reservoir (11) into which the desalinated water flows. The pressure in the storage reservoir (11) is maintained at atmosphere pressure. The desalinated water is pumped out of the storage reservoir (11) and brine water (7) is pumped out from the unit cell (5). A plurality of unit cells (5) can be contained in a large vertical shaft column (6).

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DESALINATION APPARATUS AND METHOD

FIELD OF THE INVENTION

The present invention relates to the apparatus and methods for desalination of salt water. More particularly, the present invention relates to apparatus and methods of desalination of salt water by process of reverse osmosis (RO).

BACKGROUND OF THE INVENTION

Presently, there are two general categories in seawater desalination. The first method is the evaporation of water through application of heat. Water is then collected from the condensation of the steam. The second method makes use of a natural phenomenon known as reverse osmosis, where seawater is forced within a pressure vessel against a semi-permeable membrane, which allows water to permeate. With the advancement of membrane technology, this seawater reverse osmosis (SWRO) is gaining wider acceptance as a cost effective method of desalination. Commercial SWRO plant design based on existing technologies is relatively complex which require heavy investments in mechanism, plant and equipment. Nevertheless, with the increasing global water shortages, such heavy investments are still justifiable as an option.

Most conventional SWRO desalination plants typically require pumps to create pressure within pressure vessels to effect reverse osmosis process. This is one of the main operational cost factors due to the high electrical energy requirement. There are also systems with energy recovery mechanism to reduce the total energy consumption.

One alternative method of reducing the energy requirement in pressurising the seawater for the reverse osmosis process to occur is to make

use of gravitationally induced pressure through high water column head. Since 1960's, there have been numerous patent applications making use of such hydrostatic pressures as a cost effective alternative to enable seawater reverse osmosis. Basically, there are two categories of such application, namely, onshore method and offshore method. In offshore system, reverse osmosis production unit is lowered onto sufficiently deep seabed. Water produced is then pumped up to surface for consumption.

With the onshore method, a deep vertical shaft is constructed and filled up with seawater. This creates a hydrostatic pressure for reverse osmosis units to operate at the base of the vertical shaft. Freshwater is then pumped up to the surface. Another variation to this method as disclosed in EP 0764610 is to first pump the seawater to a higher ground to create the hydrostatic pressure for the reverse osmosis production unit at ground surface level. Comparatively, this latter method may not be as energy effective since all of the seawater would have to be pumped up to the water tank above. The permeate makes up only a portion of the full seawater feed, typically between 40% to 70% depending on the various factors such as pressure head, total dissolved solid (TDS) and temperature. Whereas for the underground shaft method, only the desalted water needs to be pumped up the full height. Because the seawater intake and the brine discharge water columns are linked at the base, which liken to a U-shaped tube, the head at both water columns would equilibrate near the surface level, save for the marginal effect due to difference in density between seawater inflow and brine discharge.

US 5,916,441 discloses an on-shore method. The reverse osmosis takes place in a pressure vessel, and the shafts are suggested to be driven to 3,000 ft. The invention requires a two stage reverse osmosis process to produce drinking and agricultural use water. GB 2068774 discloses a method where reverse osmosis takes place in pressure vessels and the reverse osmosis mechanism is located in underground gallery/ cross shaft. US 4,125,463 utilises a series of independent but connected vertical reverse

osmosis pressure vessels. There is a need to remove the whole piping system to maintain the reverse osmosis membranes. EP 0968755 A2 and WO 9906323 disclose offshore methods. Here again reverse osmosis takes place in pressure vessels.

At present, commercially operated desalination plants that utilise natural hydrostatic pressure is rare and possibly, non-existent. The prior art technology as cited in documents referred to above all suffer distinct disadvantages as discussed below.

Although the energy savings are relatively substantial compared to conventional desalination methods, the lack of commercialisation of hydrostatic reverse osmosis method could be due to the following reasons:

a) High construction and operating costs

The required height or depth of water head disclosed to date is between 500m to 1000m. These are extremely deep underground shafts. Furthermore, there are also requirements for horizontal or cross shafts to house the reverse osmosis units at the base of the shafts. Although, mining technologies are available to enable the construction of such deep shafts, the infrastructure investment cost may be prohibitive to make the overall investment feasible.

b) Difficult and complicated to maintain

One of the most common problems of reverse osmosis system is the fouling and blockage of membranes. While the piping and mechanism required for hydrostatic reverse osmosis are relatively less complicated than conventional reverse osmosis systems, there is still a need to maintain the membranes within pressure vessels on a regular basis. As such, the maintenance costs can be high since work need to be undertaken within confined underground galleries at more than 500m below surface level.

c) Need for favourable geographical features

Especially for above ground hydrostatic reverse osmosis systems, the desalination plant location needs to be as close to ideal as possible to enable such system to perform economically. Otherwise the heavy infrastructure cost required would be prohibitive and cause the total production cost to be uneconomical.

Any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms a part of the prior art base or the common general knowledge in the relevant art in Singapore or elsewhere on or before the priority date of the disclosure and claims herein. All statements as to the date or representation as to the contents of these documents is based on the information available to the applicant and does not constitute any admission as to the correctness of the dates or contents of these documents.

It is an object of the present invention to provide an apparatus and method of desalination of seawater by reverse osmosis utilising natural hydrostatic pressure.

A further object of the present invention is to alleviate at least one disadvantage associated with the prior art.

SUMMARY OF THE INVENTION

This invention discloses a desalination plant comprising of at least one seawater inlet, a means to filter seawater from the seawater inlet, a means to pre-treat the filtered seawater, a means to introduce the pre-treated seawater in a controlled manner to form seawater column, at least one unit cell to contain the seawater column, at least one reverse osmosis desalination

means located in the bottom area of the unit cell, means to let brine from the unit cell into a brine discharge cell via a conduit and one-way valve means and means to let desalinated water from the reverse osmosis desalination means to a storage reservoir. The unit cell to contain seawater column has a height so that the weight of the said seawater column exerts pressure that substantially contributes to production of brine and desalinated water in the reverse osmosis desalination means. Reverse osmosis desalination means is removable from the unit cell for maintenance services. The brine in brine discharge cell is removable therefrom in a controlled manner. The desalinated water from the storage reservoir is removable therefrom in a controlled manner. A plurality of unit cells each containing a seawater column is accommodated in a vertical shaft column. The brine water from all the unit cells is introduced into one or more common brine discharge cell.

At least one extraction pipe to remove desalinated water from the storage reservoir is contained within an access well unit. The plurality of unit cells, the brine discharge cell and the access wall unit are all contained within a vertical shaft column or in a plurality of vertical shaft columns. A storage reservoir to hold desalinated water at the bottom portion of the vertical shaft is provided. A conduit with a one way pressure valve is provided to connect the unit cell and the brine discharge cell. The reverse osmosis desalination means is removable from and reintroduceable into the unit cell by hoisting means or by other mechanical handling means.

The desalinated water from the reverse osmosis desalination means flows into the storage reservoir by gravitational flow. The hydrostatic pressure acting on the reverse osmosis desalination means is in part regulated by the level of brine water maintained in the brine discharge cell and in part regulated by the seawater inflow. The rate of desalination of seawater in unit cell is increased by increasing the flow out rate of brine in the brine discharge cell. The height of the unit cell is substantially the same as the height of the

brine discharge cell. The storage reservoir is exposed to atmosphere via the access well or by other conduit means.

The invention further discloses a method to desalinate seawater by reverse osmosis by hydrostatic pressure wherein the seawater is led from a seawater inlet port to a seawater filtering system and thereafter to a pre-treatment system. The treated seawater is led into a unit cell containing at least one reverse osmosis desalination unit to form a seawater column. The desalinated water from the unit cell is led into a storage reservoir and brine water from the unit cell is led into a brine discharge cell. The desalinated water is pumped out from the storage reservoir and brine water in brine discharge cell is pumped out in a controlled manner. The seawater is led into the system by gravitational flow, or by mechanical pump means to form a seawater column. Further the hydrostatic pressure formed by the seawater column acting in the reverse osmosis desalination unit is regulated by the level of brine water in the brine discharge cell. The seawater inlet port, the seawater filtering system and the pre-treatment system are positioned above the unit cell and the brine discharge cell to take advantage of gravitational force for liquid flow. The reverse osmosis desalination units are removable for maintenance works from the unit cell by hoisting the said means from the unit cell.

A method to desalinate seawater by reverse osmosis by hydrostatic pressure, comprises the steps of, drilling a well to a pre-determined depth, introducing a vertical shaft with a storage reservoir at its basal region, placing at least one unit cell with at least one reverse osmosis desalination unit within the unit cell and placing at least one brine discharge cell in liquid communication with unit cell, introducing seawater into unit cell, pumping out desalinated water from storage reservoir and pumping out brine water from brine discharge cell. The seawater is filtered and pre-treated before introduction into unit cell.

Other aspects and preferred aspects are disclosed in the specification and / or defined in the appended claims, forming a part of the description of the invention.

The present invention has been found to result in a number of advantages, such as:

- ease of maintenance as each of the unit cell is self-contained and independent;
- no requirement for pressure vessel, hence eliminating the need for complex and complicated mechanism, piping and instrumentations;
- ease of replacement, servicing and maintenance of the modular reverse osmosis membrane;
- faster circulation of seawater and brine discharge; and
- minimal environmental impact at brine discharge point.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Further disclosure, objects, advantages and aspects of the present application may be better understood by those skilled in the relevant art by reference to the following description of preferred embodiments taken in conjunction with the accompanying drawings, which are given by way of illustration only, and thus are not limitative of the present invention, and in which:

Figure 1 is vertical cross-sectional view of the assembly of a desalination apparatus;

Figure 2 is horizontal cross-sectional view across line A-A of the apparatus shown in Figure 1;

Figure 3 is the horizontal cross-sectional view across line B-B of the apparatus shown in Figure 1; and

Figure 4 shows the sequence of removing and replacing a typical reverse osmosis membrane module in the apparatus.

DETAILED DESCRIPTION OF THE INVENTION

The invention will be described in detail with reference to a preferred embodiment. The desalination plant is located close to the sea for easy drawing of seawater for desalination preferably by gravitational flow means.

A preferred embodiment of the invention will be described by way of illustration only and not limiting in any manner. Referring to Figure 1, the seawater inlet (1) is located at sufficient depth below average mean sea level to ensure the lowest seawater level during lowest tide will be above the seawater inlet. The seawater flows by gravity to a seawater filtering system (2). Established systems known in prior art for filtering seawater is adopted to ensure seawater is filtered to remove solid particles to produce the "cleanest" possible quality using existing commercially available technology. Such technology will not be described here.

Next the raw seawater is subjected to a pre-treatment process (3) to remove organics and suspended solids in accordance with those currently practised by commercial reverse osmosis plants prior to feeding seawater into the reverse osmosis process. Once pre-treated, the seawater will be channelled through an inclined shaft (4) by gravity into a number of independent reverse osmosis production modules or unit cells (5) within a vertical shaft (6). With the low permeability ratio, the total dissolved solids

(TDS) of the brine discharge is not significantly higher than the seawater at inlet. In addition, by increasing the circulation of seawater through increasing the flow out rate of brine from the brine discharge cell, the build up of brine concentration can also be controlled and minimised. As such, the impact on marine environment at point of discharge is minimised.

Where economic feasibility or geographical constraints of the site do not allow the use of gravity induced seawater inflow, mechanical piping and pump systems can be adopted to introduce filtered and treatment sea water onto the unit cells (5).

The apparatus consists of a large diameter vertical shaft (6), preferably approximately 8 meters in diameter and 150 meters deep or more as appropriate. The apparatus is installed in a well which may be drilled in land surface or may be drilled in offshore areas using techniques known to the art. The well is drilled to a predetermined depth to accommodate the apparatus. These dimensions are subject to the required production rate as well as the hydrostatic pressure required to enable the reverse osmosis process to occur. These are further dictated by, but not limited to, the salinity of seawater, permeability of the reverse osmosis membrane and the desired yield of freshwater from the whole system. In the present invention the depth of the vertical shaft (6) would be about 150 meters below ground or more. At this length of the vertical shaft (6), the water head in the unit cell (5) that is the seawater column would be relatively lower than most conventional pressure heads used in reverse osmosis systems. As explained later, shorter water heads would reduce permeability of the seawater. This setback can be offset or compensated by the provision of greater number of reverse osmosis modules (9) within the vertical shaft (6). Alternatively, additional plants working in series can be provided to achieve the required volume. Further shallower vertical shaft also reduces the initial capital investment costs. Within the shaft are at least three main types of vertical wells, namely, reverse osmosis production well or termed as unit cell (5) where the reverse osmosis

process takes place; brine discharge well (7), and an access well (8). These vertical wells may be arranged in any other configurations. In a preferred embodiment, the unit cell (5), the brine discharge well (7), and the access well (8) are arranged in honeycomb like formation.

There are a number of the unit cells (5) constructed forming a series of vertical wells. In the present embodiment there are seven unit cells (5). Another access well (8) not necessarily of the same shape and dimension as unit cell (5) is provided. All the seven unit cells (5) and the access well (8) are preferably of equal dimensions. They are placed along the inner circumferential edge of the unit cell (5) as illustrated in Figures 2 and 3. The unit cells (5) are configured to utilise the maximum space beyond the central core region comprising the brine discharge well (7). Each of the unit cell 5 is an independent well where reverse osmosis process takes place at the reverse osmosis membrane module (9) located at the basal portion of each well. The reverse osmosis membranes are exposed directly to the hydrostatically pressured seawater. The permeate is allowed to flow freely towards the outlet pipe (10) at the bottom of the reverse osmosis membrane module (9), which then flows by gravitational force into the storage reservoir (11) at the base of the vertical shaft (6). The bottom region of the vertical shaft (6) below the unit cell is storage reservoir (11) to receive permeate from reverse osmosis membrane module (9). All the reverse osmosis membrane modules (9) are standardised so that they are all interchangeable. This feature would avoid high inventory of spare reverse osmosis membrane modules (9), which can be costly.

The water in the storage reservoir (11) is then pumped to the surface for distribution via the extraction pump (15) and the extraction pipe (16). The storage reservoir (11) is exposed to the atmosphere via the access wall (8), Thus, the storage reservoir (11) is at atmosphere pressure.

Alternatively, the desalted water from the reservoir could be pumped to an underground cavern for storage and future use; or discharged into aquifers to recharge depleted groundwater or for groundwater extraction at a faraway distance. In situations where groundwater has been over extracted, the recharging of aquifer by this way would also minimize the possible ground settlement of the urban or residents areas.

The near brine quality water at the base of all the unit cells (5) is then channelled via a pipe (12) to the central brine discharge well (7). There is a one-way pressure valve (13) installed to avoid any backflow of brine into the unit cell 5. This pressure valve (13) also enables any one of the unit cells (5) to be totally drained during maintenance independent of other unit cells. A pump (14) is situated at the top of the brine discharge well (7) to discharge the central brine discharge as well as to induce the circulation of raw seawater from the unit cell (5) to the central core brine discharge well (7) through the connecting pipe (12). By controlling the rate of the brine discharge pump (14), the circulation of the seawater can be regulated. For instance, to accelerate the circulation, the flow rate of the brine discharge pump (14) is increased. When the water level within the core brine discharge well (7) reduces, an imbalance level of hydrostatic pressure is being created between the discharge well (7) and the unit cell (5). The seawater level at the unit cell (5) referred to also as the seawater column is always kept at the highest point through the continuous flow of pretreated seawater from the inclined shaft (4). This differential hydrostatic pressure would cause the seawater from the unit cell (5) to flow into the central core brine discharge well (7). Similarly, by reducing the pumping rate of the brine discharge pump (14), the circulation of the seawater is accordingly slower. An optimised flow rate would minimise clogging up of the reverse osmosis membrane.

The design and construction of the reverse osmosis membrane module (9) enables easy set up and removal and hence eases the on-going maintenance of the system. The whole reverse osmosis membrane module

(9) can be removed and lifted up to the ground level for regular cleaning and maintenance; and then lowered back into the unit cell (5) by hoisting means or by other mechanical handling means.

Figure 4 shows the sequence in replacing the reverse osmosis membrane module (9). The reverse osmosis membrane module (9) within each unit cell (5) is replaced one at a time and hence, would not affect the continuous production of the desalinated water. During Stage 1, the inflow of pretreated water is stopped and a pump (16) is used to discharge the seawater within the unit cell (5). The one-way pressure valve (13) placed in the conduit (12) connecting the unit cell (5) and the central core (7) will stop any backflow of seawater from the central core (7) into the unit cell (5) due to the imbalance hydrostatic pressure created. A vertical hoist (17) is then fixed to the reverse osmosis membrane module (9). As shown in Stage 2, once the seawater level is discharged until a level in the unit cell (5) below the reverse osmosis membrane module (9), the pump (16) is stopped. The reverse osmosis membrane module (9) is then lifted up and removed for servicing and cleaning as illustrated in Stage 3 and Stage 4 respectively. Referring to Stage 5, a new or clean reverse osmosis membrane module (9) is then lowered and connected to the outlet pipe (10) by using a self locking coupler (not shown). In Stage 6, which is the final stage, the pre-treated seawater is released to flow back into the unit cell (5) via the inclined shaft 4. Once the seawater level reaches the top of the unit cell (5), the desalination process recommences. An alternate method of replacing the reverse osmosis membrane module (9) does not require the discharging of the pretreated seawater within the unit cell (5). This can be achieved with a specially designed self-locking coupler between the reverse osmosis membrane module (9) and the outlet pipe (10). Such coupler enables the reverse osmosis membrane module (9) to be replaced while submerged under the water column, and prevents any seawater flowing into the storage reservoir (11) through outlet pipe (10). The reverse osmosis membranes in the reverse osmosis module in each of the unit cells are built of commercially available

membranes. As the size of the reverse osmosis membranes are preferably uniform, the reverse osmosis membranes can be standardised. With the standardisation of the reverse osmosis membrane module, replacement of defective membrane modules can be carries out much more efficiently. Further the removed reverse osmosis membrane modules can then be serviced, maintained and shared as back up module.

It will be appreciated that the plurality of unit cells (5) can be arranged in any other manner, subject to the unit cells being in liquid communication with the central core (7) via a connecting pipe (12). There could also be a plurality of brine discharge wells (7) wherein each brine discharge well serves at least one unit cell (5). Where the vertical shaft is large, there could be provided a cluster comprising of unit cells (5) and brine discharge wells (7) in each cluster.

There could be more than one reverse osmosis membrane module (9) in each unit cell (5) subject to a spatial configuration wherein each reverse osmosis membrane module (9) is removable from the unit cell for routine maintenance work. The outlet pipe (10) from each module (9) is in liquid connection to the storage reservoir (11). Where the output of desalinated water from the unit cells (5) is large, there can be provided more than one extraction pipe (16) and pumps (15) to pump out the desalinated water.

It will be appreciated that each of reverse osmosis production unit or unit cell (5) is self contained and independent of other unit cells. This configuration simplifies on-going maintenance of each unit all and in particular the membrane modules (9). Each unit cell (5) can be drained, the reverse osmosis membrane filler(s) within it can be lifted up for cleaning and maintenance without significantly interrupting the operation of the other unit cells. The reverse osmosis membranes can be lifted and reintroduced into the unit cells by a fully mechanised means. The honeycombs like assembly of unit cells within a vertical shaft also results in saving of space. As such the

invention provides an economical and feasible method of desalination of seawater.

It will be further appreciated that an assembly of desalination plants as described above can be arranged subject to the arrangement that a common sea water inlet, a common means to filter the seawater and a common seawater treatment means can be provided.

Similarly the reservoirs at the base of each vertical shaft can be connected by conduit means and a common or single extraction pipe can be provided to remove the desalinated water from the reservoirs so connected.

One of the major advantages of the present invention is the elimination of the need of pressure vessels as in prior art. The reverse osmosis membrane immersed in the well is directly exposed to hydrostatic pressure of the salt water. In conventional practice, the membrane removes the need for complex and complicated mechanism piping and instrumentations, resulting in a overall simplified, less expensive desalination plants.

As the height of the waterhead in the unit cell (5) can be individually controlled, the invention offers the possibility of using different types of membranes, ranging from low pressure to high pressure reverse osmosis membrane, enabling the maximising of desalination rates in the vertical shaft.

As the seawater inlet is constructed below the seawater levels, it enables the seawater to flow into pre-treatment chamber by gravity. Similarly, the pre-treated seawater then flows into reverse osmosis unit cells by gravity. Thus by using gravity induced flow, a saving of energy cost is realised.

While this invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modification(s). This application is intended to cover any variations uses or

adaptations of the invention following in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth.

As the present invention may be embodied in several forms without departing from the spirit of the essential characteristics of the invention, it should be understood that the above described embodiments are not to limit the present invention unless otherwise specified, but rather should be construed broadly within the spirit and scope of the invention as defined in the appended claims. Various modifications and equivalent arrangements are intended to be included within the spirit and scope of the invention and appended claims. Therefore, the specific embodiments are to be understood to be illustrative of the many ways in which the principles of the present invention may be practiced. In the following claims, means-plus-function clauses are intended to cover structures as performing the defined function and not only structural equivalents, but also equivalent structures. For example, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface to secure wooden parts together, in the environment of fastening wooden parts, a nail and a screw are equivalent structures.

"Comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof."

CLAIMS

1. Desalination plant comprising of:
at least one seawater inlet;
means to filter seawater from the seawater inlet;
means to pre-treat the filtered seawater;
means to introduce the pre-treated seawater in a controlled manner into seawater column;
at least one unit cell to contain a seawater column;
at least one reverse osmosis desalination means located in the bottom area of the said unit cell;
means to let brine from the unit cell into a brine discharge cell via a conduit and one-way valve means; and
means to let desalinated water from the reverse osmosis desalination means to a storage reservoir;

wherein said at least one unit cell to contain seawater column has a height so that the weight of the said seawater column exerts pressure that substantially contributes to production of brine and desalinated water in the reverse osmosis desalination means characterised in that reverse osmosis desalination means is removable from the unit cell for maintenance services;
brine in brine discharge cell is removable therefrom in a controlled manner; and
desalinated water from the storage reservoir is removable therefrom in a controlled manner.

2. Desalination plant according to claim 1 characterised in that a plurality of unit cells each containing a seawater column is accommodated in a vertical shaft column.

3. Desalination plant according to claim 1 or 2 characterised in that the brine water from all the unit cells is introduced into a common brine discharge cell.

4. Desalination plant according to claim 1, 2 or 3 characterised in that at least one extraction pipe to remove desalinated water from the storage reservoir is contained within an access well unit.

5. Desalination plant according to any one of claims 1 to 4 characterised in that a plurality of unit cells, a brine discharge cell and the access well unit are all contained within a vertical shaft column or in a plurality of vertical shaft columns.

6. Desalination plant according to claim 5 characterised in that vertical shaft column includes a storage reservoir to hold desalinated water at the bottom portion.

7. Desalination plant according to any one of claims 1 to 6 characterised in that a conduit with a one way pressure valves means is provided to connect the unit cell and the brine discharge cell.

8. Desalination plant according to any one of claims 1 to 7 characterised in that the reverse osmosis desalination means is removable from and reintroduceable into the unit cell by hoisting means or by other mechanical handling means.

9. Desalination plant according to any one of claims 1 to 8 characterised in that desalinated water from the reverse osmosis desalination means flows into a storage reservoir by gravitational flow.

10. Desalination plant according to any one of claims 1 to 9 characterised in that hydrostatic pressure acting on the reverse osmosis desalination means is in part regulated by the level of brine water maintained in the brine discharge cell and in part regulated by the seawater inflow.

11. Desalination plant according to any one of claims 1 to 10 characterised in that the circulation rate of seawater in unit cell is increased by increasing the flow out rate of brine in the brine discharge cell.

12. Desalination plant according to claims 1 to 11 characterised in that the height of the unit cell is substantially the same as the height of the brine discharge cell.

13. Desalination plant according to claims 1 to 12 wherein the storage reservoir is exposed to atmosphere via the access well.

14. An assembly of desalination plants wherein each desalination plant is as claimed in any of claims 1 to 13 but wherein all desalination plants are fed from at least one seawater inlet, at least a single means to filter seawater from the seawater inlet, and at least a single means to pre-treat the filtered seawater.

15. A method to desalinate seawater by reverse osmosis by natural pressure, characterised in that:

(i) the seawater is led from a seawater inlet port to a seawater filtering system and thereafter to a pre-treatment system;

(ii) treated seawater from step (i) is led into a unit cell containing at least one reverse osmosis desalination means;

(iii) desalinated water from the unit cell is led into a storage reservoir;

(iv) brine water from the unit cell is led into a brine discharge cell;

(v) desalinated water is pumped out from the storage reservoir; and

(vi) brine water in brine discharge cell is pumped out in a controlled manner.

16. A method as claimed in claim 15 wherein seawater from step (i) is led by gravitational flow, or by mechanical pump means.

17. A method as claimed in claim 15 or 16 characterised in that hydrostatic pressure acting in the reverse osmosis desalination means is regulated by the level of brine water in the brine discharge cell and the seawater inflow.

18. A method as claimed in claim 15, 16 or 17 characterised in that the seawater inlet port, the seawater filtering system and the pre-treatment system are positioned above the unit cell and the brine discharge cell.

19. A method as claimed in any one of claims 15 to 18 characterised in that the reverse osmosis desalination means are removable for maintenance works from the unit cell by hoisting the said means from the unit cell.

20. A method to desalinate seawater by reverse osmosis by natural pressure, comprising the steps of:

drilling a well to a pre-determined depth;

introducing at least one vertical shaft with a storage reservoir at its basal region in said shaft into said well and, said storage reservoir subjected to atmosphere pressure;

placing at least one unit cell with at least one reverse osmosis desalination means within the unit cell and placing at least one brine discharge cell in liquid communication with unit cell;

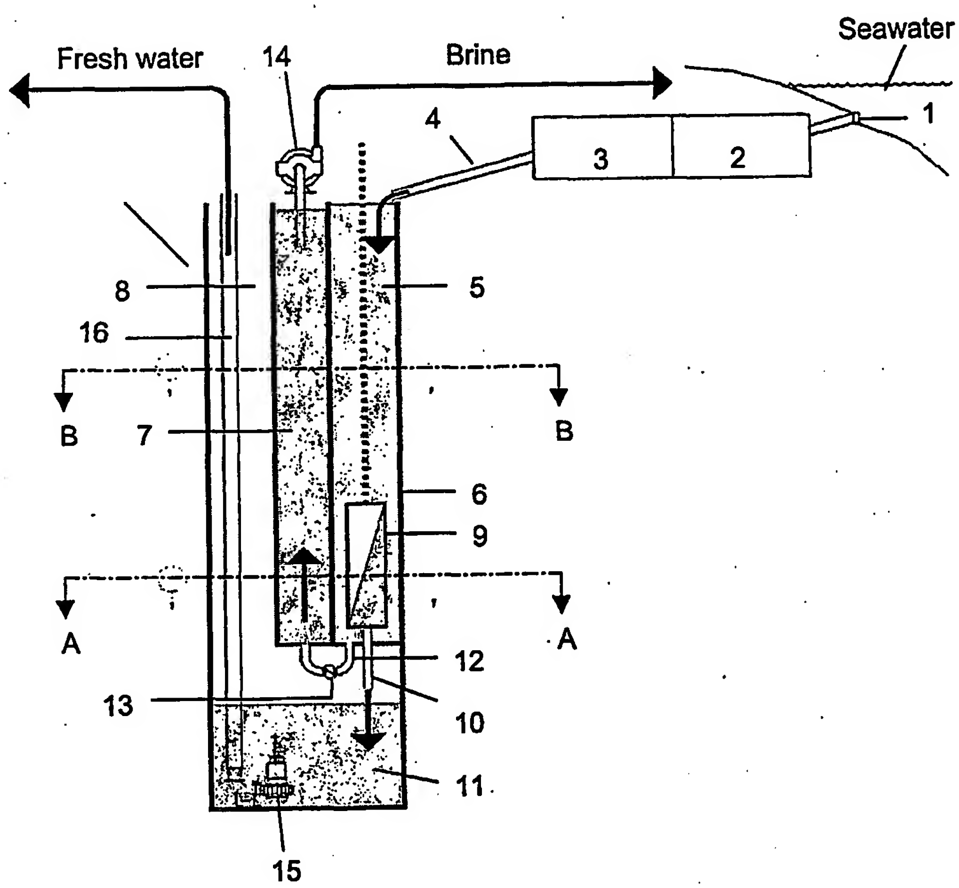
introducing seawater into unit cell;

pumping out desalinated water from storage reservoir; and

pumping out brine water from brine discharge cell.

21. A method as claimed in claim 20, wherein seawater is filtered and pre-treated before introduction into unit cell.

22. A method as claimed in claim 21, wherein the pre-treated seawater flow into unit cell by gravitational force into the unit cell or by mechanical pump means.



Fresh water
14
Brine
Seawater
1
4
3
2
8
5
16
B
7
B
6
9
A
A
12
13
10
11
15

Figure 1

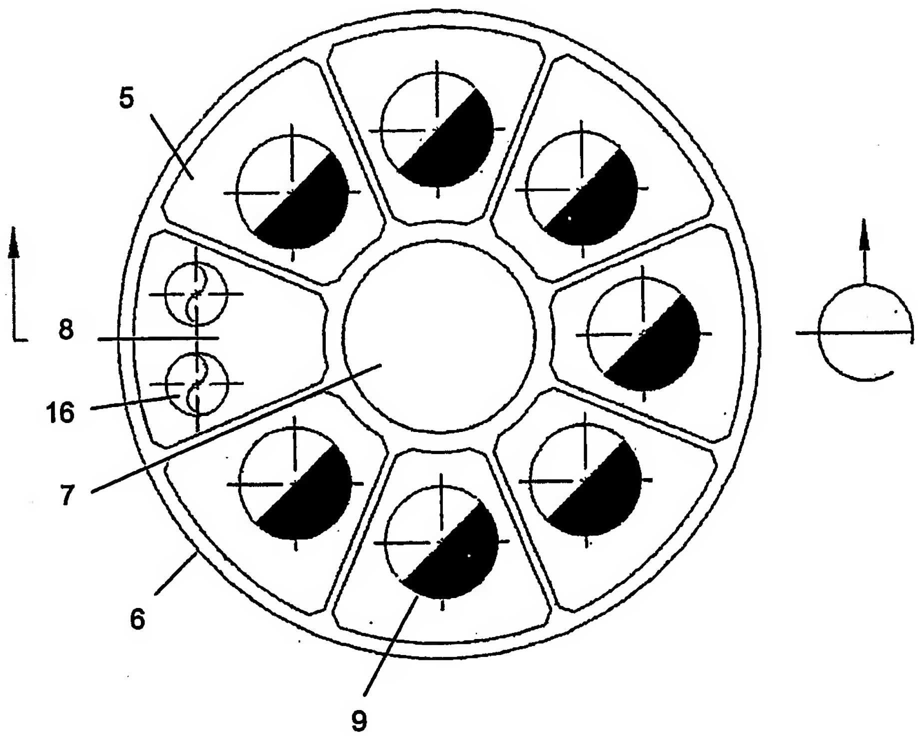


Figure 2

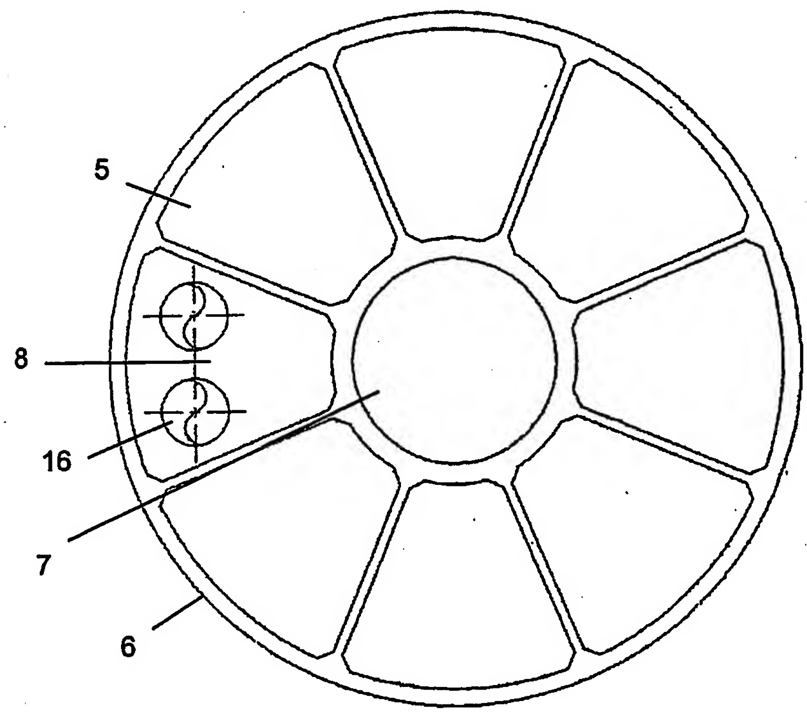


Figure 3

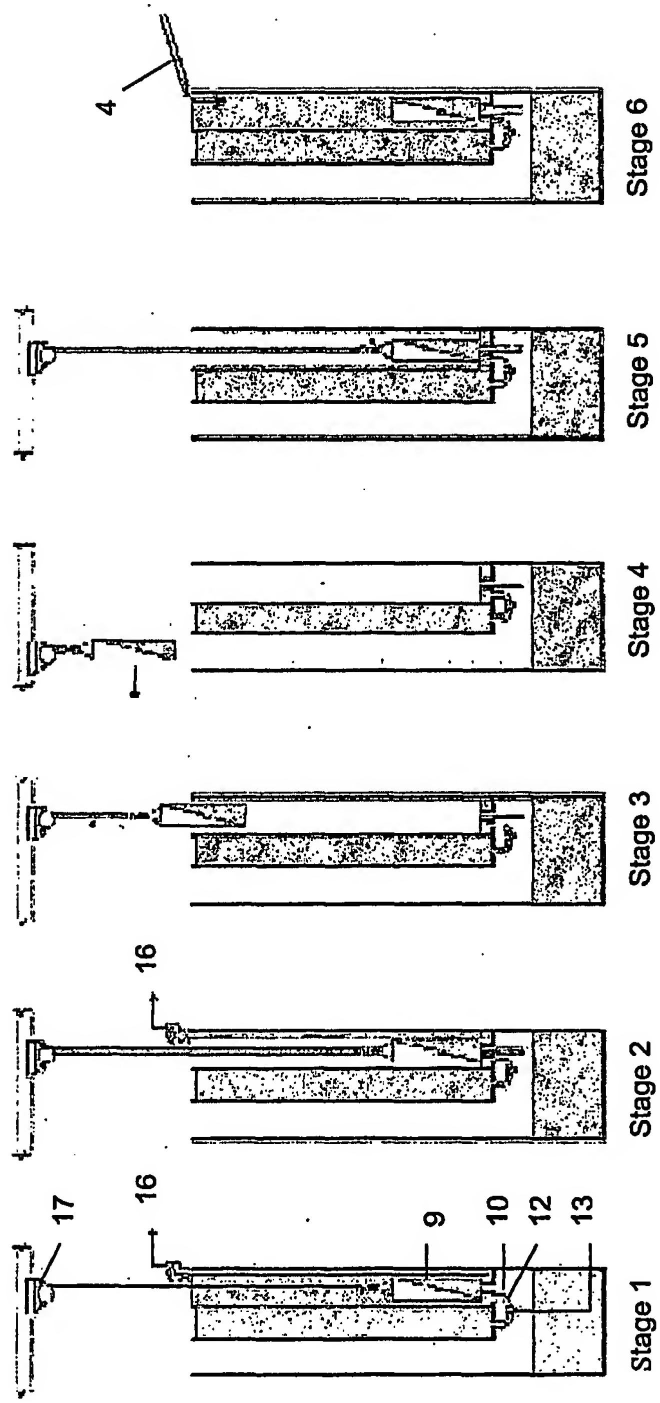

4
Stage 6
Stage 5
Stage 4
Stage 3
16
Stage 2
17
16
9
10
12
13
Stage 1

Figure 4

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2005/000233

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: C02F 001/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI:- C02F 001/44, 130/08 and keywords desalinat+ and osmosis and hydrostatic or head or column and seawater or saltwater

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, 4125463, A (CHENOWETH) 14 November 1978	1-22
X	GB, 2068774, A (MESPLE) 19 August 1981	1-22
X	US, 5366635, A (WATKINS) 22 November 1994	1-22
X	US, 5914041, A (CHANCELLOR) 22 June 1999	1-22

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 August 2005	24 AUG 2005

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, 5916441, A (RAETHER) 29 June 1999	1-22
X	US, 5944999, A (CHANCELLOR) 31 August 1999	1-22
X	US, 2002/0125190, A1 (BOSLEY) 12 September 2002	1-22
X	EP, 0764610, B1 (RIAL) 8 December 1999	1-22

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INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. PCT/SG2005/000233

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4125463						
GB	2068774	BE	887149	BR	8100420	DE	3103224
		ES	8101023	FR	2475029	GR	72978
		JP	56124487	MA	19055	NL	8100185
		SE	8100116				
US	5366635	AU	56082/94	WO	9412267		
US	5914041	AU	28766/99	AU	40984/99	AU	42393/97
		AU	71130/98	CA	2264853	CA	2282403
		CA	2321820	CN	1233972	CN	1252738
		CN	1300235	EP	0930931	EP	0983115
		EP	1062026	HK	1024652	ID	23391
		IL	128621	IL	131491	IL	138105
		NO	991014	NO	20004263	US	5944999
		US	5980751	US	6041829	US	6149393
		US	6521127	US	6547965	US	6589423
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		CA	2264853	CA	2282403	CA	2321820
		CN	1233972	CN	1252738	CN	1300235
		EP	0930931	EP	0983115	EP	1062026
		HK	1024652	ID	23391	IL	128621
		IL	131491	IL	138105	NO	991014
		NO	20004263	US	5914041	US	5944999
		US	5980751	US	6041829	US	6149393
		US	6521127	US	6547965	US	6589423
		WO	9809718	WO	9846338	WO	9943421
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		WO	0059612				
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		OA	10387	WO	9631436	ZA	9602680

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX